EVALUATION OF POTENTIAL HEALTH EFFECTS OF EATING FISH FROM SELECTED WATER BODIES IN THE NORTHERN SIERRA NEVADA FOOTHILLS (NEVADA, PLACER, AND YUBA COUNTIES): GUIDELINES FOR SPORT FISH CONSUMPTION

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FOREWORD

This report provides guidelines for consumption of various fish species taken from Camp Far West, Lake Combie, Lake Englebright, Rollins Reservoir, Scotts Flat Reservoir, and portions of the Bear River, Yuba River and Deer Creek area in Nevada, Placer and Yuba Counties. (These areas are collectively referred to as the "Sierra Lakes" region in this advisory.) These guidelines were developed as a result of findings of high mercury levels in fish tested from these water bodies and are provided to protect against possible adverse health effects from methylmercury as consumed from mercury-contaminated fish. This report provides background information and a description of the data and criteria used to develop the guidelines.

To protect public health in the period while this technical support document was being prepared for public comment, the Counties of Nevada, Placer and Yuba in consultation with the Office of Environmental Health Hazard Assessment, issued an interim public health notification for fish from the affected area. This notification is included in Appendix 2. Once completed, the advisory contained herein will become the final state advisory.

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EXECUTIVE SUMMARY

The United States Geological Survey (USGS) conducted a reconnaissance survey of mercury concentrations in edible fish tissue in three northwestern Sierra Nevada watersheds affected by historical gold mining. Samples of nine sport fish species were collected from five reservoirs and 14 stream sites in the South Yuba, Deer Creek, and Bear River watersheds (the "Sierra Lakes" region). Data were evaluated by the Office of Environmental Health Hazard Assessment (OEHHA) in this report to assess the likelihood and degree of human exposure to mercury in fish and to determine whether there may be potential adverse health effects associated with consuming sport fish from the area.

More than 95 percent of the mercury found in fish occurs as methylmercury, which is a highly toxic form of the element. Fish consumption accounts for almost 100 percent of the average daily methylmercury intake in adults not occupationally exposed to mercury. The critical target of methylmercury toxicity is the nervous system, particularly in developing organisms such as the fetus and young children. Significant methylmercury toxicity can occur to the fetus during pregnancy even in the absence of symptoms in the mother. The United States Environmental Protection Agency (U.S. EPA) has set a reference dose (RfD, that is the daily exposure likely to be without significant risks of deleterious effects during a lifetime) for methylmercury of 1×10^{-4} mg/kg-day, based on developmental neurologic abnormalities in infants exposed *in utero*. A second RfD of 3×10^{-4} mg/kg-day has been set based on central nervous system effects (ataxia and paresthesia) in adults. In this advisory, the RfD based on effects in infants will be used for females of childbearing age and children aged 17 and younger. The adult RfD will be used for females beyond their childbearing years and adult males.

Potential methylmercury exposures using different consumption scenarios were evaluated for persons consuming fish from the Sierra Lakes region. Data were sufficient so that exposures could be well characterized at only seven species/site combinations. These were: spotted bass at Camp Far West Reservoir, largemouth bass at Lake Combie, smallmouth bass at Lake Englebright, channel catfish from Rollins Reservoir, brown trout from Deer Creek, and rainbow trout from the Bear River and South Yuba River. The health evaluation found that fishers consuming these species from these sites are potentially exposed to methylmercury concentrations above the reference dose.

A standard exposure and risk assessment could not be conducted for other site/species combinations because of insufficient sample size; however, the evaluation of supporting data did allow for development of additional consumption guidelines. Supporting data were used in the following sequence: 1) contamination data for another closely related species at a similar trophic level available from the same site, and 2) contamination data for the same species available from a nearby site with similar hydrogeological and/or chemical contamination characteristics. When neither type of supporting data was available for a particular site/species combination, the U.S. EPA national freshwater sport fish consumption advice for pregnant or nursing women and young children was provided for these sensitive populations. OEHHA recommends that children through age 17 also follow this advice because of continued nervous system development through adolescence. For females beyond their childbearing years and adult males, the OEHHA general advice for sport fish consumption was given.

The risk characterization and evaluation of supporting data indicated that the reference dose for methylmercury was consistently exceeded at typical consumption rates for numerous species and sites. Consumers should be informed of the potential hazards from eating fish from these areas, particularly those hazards relating to the developing fetus and children. All individuals, especially females of childbearing age and children aged 17 and younger, are advised to limit their fish consumption to reduce methylmercury ingestion to a level near the reference dose. To help sport fish consumers achieve this goal, OEHHA has developed separate advisories for black bass species (largemouth, smallmouth and spotted bass) and channel catfish for the following five reservoirs in the Sierra Lakes region: Camp Far West Reservoir, Lake Combie, Lake Englebright, Rollins Reservoir and Scotts Flat Reservoir. Additionally, OEHHA has developed separate advisories to limit consumption of trout species for sections of the Bear River, South Yuba River and Deer Creek. As noted above, for fish species not included in these advisories but found in these water bodies (e.g., bluegill and green sunfish), OEHHA recommends separate advisories for adult males and females beyond their childbearing years as well as women of childbearing age and children aged 17 and younger. These advisories are contained in this report and are available online at: **http://www.oehha.ca.gov/fish/so_cal/nosierra.html**.

For general advice on how to limit your exposure to chemical contaminants in sport fish (e.g., eating smaller fish of legal size), see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html). Site specific advice for other California water bodies can be found online at: **http://www.oehha.ca.gov/fish/so_cal/index.html**. It should be noted that, unlike the case for many organic contaminants, various cooking and cleaning techniques will not reduce the methylmercury content of fish. Meal sizes should be adjusted to body weight as described in this report on page 27.

Based on the evaluation of the USGS data showing elevated levels of mercury present in fish, OEHHA recommends that females of childbearing age and children aged 17 and younger adhere to the following consumption guidelines for fish taken from the Sierra Lakes area.

FISH CONSUMPTION GUIDELINES FOR FEMALES OF CHILDBEARING AGE AND CHILDREN AGED 17 AND YOUNGER	
LOCATION AND FISH SPECIES	**DO NOT EAT MORE THAN***
	MEALS PER MONTH
Camp Far West Reservoir	
All Bass	**DO NOT EAT**
Channel Catfish	**2**
Lake Combie, Lake Englebright, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	**1**
Channel Catfish	**2**
Bear River below Highway 20, South Yuba River Below Lake Spalding	
All Trout	**4**
Deer Creek	
All Trout	**2**
All of the Above Sites**	
Other sport fish species	**4**

* Consumption limits for each species assume that no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly.

**All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. If consumption advice is not available for that species at any site, follow U.S. EPA national guidance for pregnant or nursing women and young children recommending consumption of no more than one meal per week of freshwater sport fish.

Fish are nutritious and should be part of a healthy, balanced diet. As with many other kinds of food, however, it is prudent to consume fish in moderation. OEHHA provides this consumption advice to the public so that people can continue to eat fish without putting their health at risk.

OEHHA recommends that females beyond their childbearing years and adult males adhere to the following consumption guidelines for fish taken from the Sierra Lakes area.

FISH CONSUMPTION GUIDELINES FOR FEMALES BEYOND THEIR CHILDBEARING YEARS AND ADULT MALES

LOCATION AND FISH SPECIES	DO NOT EAT MORE THAN* MEALS PER MONTH
Camp Far West Reservoir	
All Bass	**2**
Channel Catfish	**4**
Lake Combie, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	**2**
Channel Catfish	**4**
Lake Englebright	
All Bass	**4**
Channel Catfish	**4**
Bear River below Highway 20, South Yuba River Below Lake Spalding	
All Trout	**12**
Deer Creek	
All Trout	**8**
All of the Above Sites**	
Other sport fish species	**12**

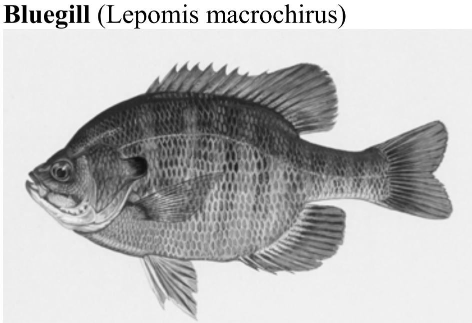
* Consumption limits for each species assume that no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly.

**All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. For fish species caught from the listed water bodies but not included in the guidelines, OEHHA recommends consumption of no more than 12 meals per month of any fresh water sport fish from the Sierra Lakes region.

Sierra Lakes Sport Fish

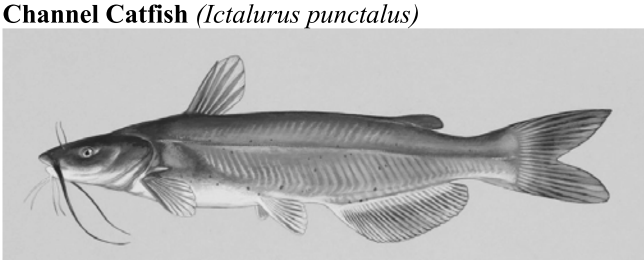
Black Crappie *(Pomoxis nigromaculatus)*

Bluegill (Lepomis macrochirus)

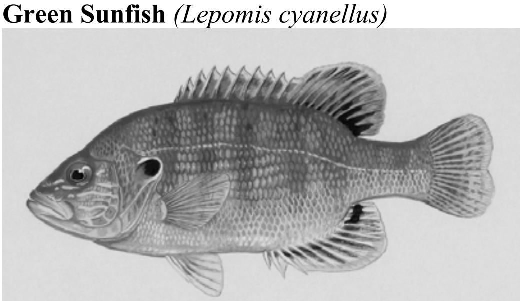


Brown Trout *(Salmo trutta)*

Channel Catfish *(Ictalurus punctalus)*

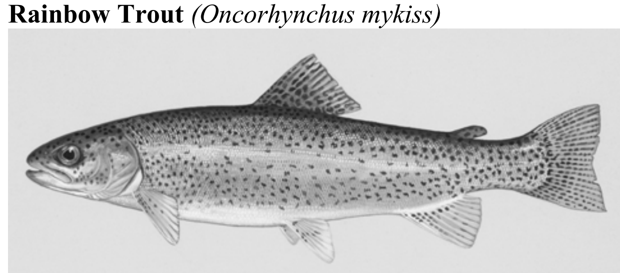


Green Sunfish *(Lepomis cyanellus)*

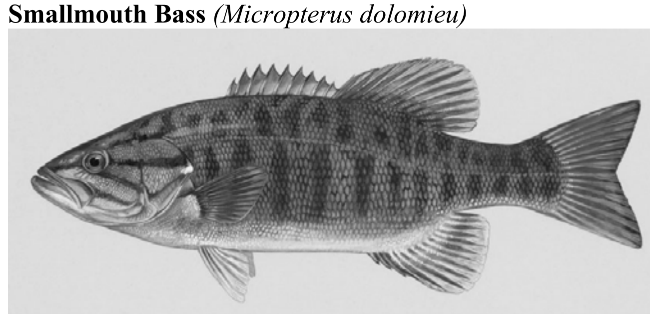


Largemouth Bass *(Micropterus salmoides)*

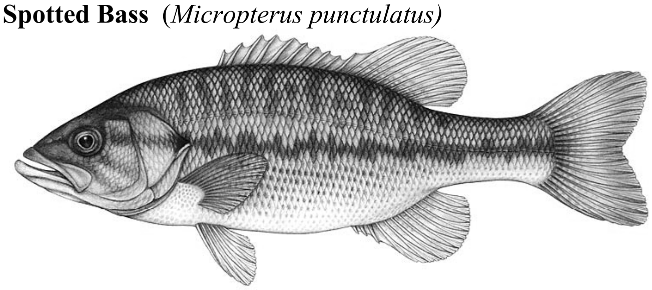
Rainbow Trout *(Oncorhynchus mykiss)*



Smallmouth Bass *(Micropterus dolomieu)*



Spotted Bass (*Micropterus punctulatus)*



Note: Pictures are not to scale.

INTRODUCTION

Recent studies have suggested that mercury associated with historic gold mining has bioaccumulated in some watersheds in the northwestern Sierra Nevada (Slotton et al., 1997; Domagalski, 1998). In response to this information, the United States Geological Survey (USGS) conducted a reconnaissance survey of mercury concentrations in edible fish tissues in the region (May et al., 2000). Sport fish were collected from five reservoirs and 14 stream sites in the South Yuba River, Deer Creek, and Bear River watersheds, including two reference (control) sites believed to be upstream from previous mining locations (Figure 1).

Preliminary review of the data from the USGS study (May et al., 2000) by the Office of Environmental Health Hazard Assessment (OEHHA) indicated that a health evaluation of the results was justified for people eating sport fish from these water bodies. This health evaluation was based on the potential exposure to methylmercury through consumption of fish from this area and addresses the associated potential health risks of such exposure. Almost all sport and commercial fish contain measurable levels of mercury; however, exposure can be increased to unacceptable levels in areas where environmental mercury contamination is especially high.

OEHHA is the agency responsible for evaluating potential public health risks from chemical contamination of sport fish. This includes issuing advisories, when appropriate, for the State of California. OEHHA's authorities to conduct these activities are based on mandates in the California Health and Safety Code, Section 205 (protecting public health), and Section 207 (advising local health authorities), and the California Water Code Section 13177.5. Fish advisories developed by OEHHA are published in the California Sport Fishing Regulations and California Sport Fish Consumption Advisories.

In evaluating the USGS data, it was determined that many fish species had high levels of mercury, including some that exceeded the Food and Drug Administration (FDA) action level for mercury of 1.0 ppm. Because fish consumption advice was not currently in place in the region, it was determined that a health evaluation was appropriate.

BACKGROUND

USGS collected 161 fish samples for analysis from August to October 1999, at 22 designated sites in the Sierra Lakes region (May et al., 2000). These included samples from 14 stream sites (four along the South Yuba River or its tributaries; three along Deer Creek or Little Deer Creek; and seven along the Bear River or its tributaries) and eight sites within five reservoirs. Reservoirs that were selected for study included one on the Yuba River (Lake Englebright), one on Deer Creek (Scotts Flat Reservoir), and three on the Bear River (Rollins Reservoir, Lake Combie, and Camp Far West Reservoir). Reservoir characteristics described below were obtained from the California Department of Water Resources (DWR, 1993; 2001). Fish stocking and prevalence data were obtained from California Department of Fish and Game (DFG) (Hiscox, 2001, personal communication; Kopperdahl, 2001, personal communication) and Stienstra (1999).

Yuba River Watershed

Lake Englebright is an 815-acre reservoir with a crest elevation of 542 feet and a storage capacity of 70,000 acre-feet. In 1999, the year fish were collected for this study, monthly average storage on Lake Englebright ranged from 60,803 to 71,192 acre-feet, the most stable water level of any of the reservoirs sampled by USGS. The reservoir drains 1,100 square miles, the largest drainage area of the reservoirs in the study. In 1999, Lake Englebright was stocked with 18,000 rainbow trout. It had been most recently stocked with brown trout (1,800) in 1997. Bass are also known to populate the lake.

Deer Creek Watershed

With a crest elevation of 3,085 feet, Scotts Flat Reservoir is the highest reservoir in the study. The storage capacity is 49,000 acre-feet; monthly average storage ranged from 32,259 to 48,547 acre-feet in 1999. Scotts Flat Reservoir has a surface area of 725 acres and drains 20 square miles, the smallest drainage area of the five reservoirs. In 1999, upper and lower Scotts Flat Reservoir was stocked with a total of 12,700 rainbow trout. In some years, the lake may also be stocked with a much smaller number of brown trout, which have been known to exceed ten pounds when caught. The lake is heavily populated with smallmouth bass.

Bear River Watershed

Rollins Reservoir is an 825-acre reservoir and, with a crest elevation of 2,187 feet, is the second highest reservoir in the study. The storage capacity of this reservoir is 66,000 acre-feet, with monthly averages ranging from 50,600 to 65,988 acre-feet in 1999. Rollins Reservoir drains 104 square miles. In 1999, it was stocked with 5,900 brown trout and 8,300 rainbow trout. This lake is also fished for bass, bluegill, crappie, and channel catfish.

Lake Combie is a 360-acre reservoir with a storage capacity of 5,555 acre-feet, the smallest reservoir in the study. In 1999, monthly average storage ranged from 4,330 to 5,555 acre-feet. Lake Combie drains 130 square miles and has a crest elevation of 1,610 feet. DFG does not stock Lake Combie and more detailed fishing information was not identified for this reservoir.

Camp Far West Reservoir has the lowest elevation of any water body in the study at 320 feet. With a storage capacity of 103,000 acre-feet, Camp Far West is by far the largest water body sampled by USGS. Average monthly storage ranged from 52,600 to 106,600 acre-feet in 1999, making this reservoir the most variable in water level. Camp Far West Reservoir has a surface area of 2,680 acres, with a 285 square mile drainage area. In previous years, Camp Far West Reservoir was stocked with spotted and striped bass and is considered one of the best bass fishing spots in the Central Valley. The reservoir is one of the few water bodies in California to contain a self-sustaining population of striped bass (Madgic, 1999), the lake record catch of which is reported to be 44 pounds. The reservoir is also fished for crappie.

Nine sport fish species were caught at the above reservoir and stream sites by electrofishing equipment, hook and line, or dip netting. These included black crappie, bluegill, green sunfish, rainbow trout, brown trout, smallmouth bass, largemouth bass, spotted bass, and channel catfish. Fish were measured and weighed; boneless and skinless fillets of 141 samples (131 single samples and ten composite samples of three fish each) were submitted to the Trace Element Research Laboratory (TERL) and Frontier Geosciences Laboratory (FGS) for total mercury analyses. Mercury levels were determined by cold-vapor atomic absorption spectroscopy and cold-vapor atomic fluorescence spectroscopy (CVAFS) at TERL and FGS, respectively. A more detailed description of sampling and analytical procedures can be found in the USGS report (May et al., 2000).

It is not possible to determine in advance how many samples of each fish species from each site will be necessary in order to statistically interpret contamination data for consumption advisories. However, U.S. EPA does recommend a minimum of three replicate composite samples of three fish per composite (nine total fish) in order to begin assessing the magnitude of contamination at a site. U.S. EPA also recommends that at least two fish species be sampled per site. Although composite analysis is generally the most cost-efficient method of estimating the average concentration of chemicals in a fish species, individual sampling provides a better measure of the range and variability of contaminant levels in a fish population (U.S. EPA, 2000a). Using these guidelines, OEHHA believes that a minimum of three replicates of three fish per composite or, preferably, nine individual fish samples of multiple species from each site should be analyzed for this type of pilot study. Fish samples should be collected from multiple (legal/edible-) size classes. Following this sampling protocol will allow estimation of the range and variation of contaminant concentrations at a particular site and derivation of a representative mean concentration for use in exposure assessment.

In large water bodies and in those with local differences in geology, ecology, hydrology, or pollutant sources, multiple sites should be sampled. Such differences may occur among the reservoirs, creeks and rivers in this study, but they are less pronounced within single water bodies. Thus, in this evaluation, the five individual reservoirs as well as the mining areas of the Bear and South Yuba Rivers and Deer Creek were regarded as separate individual sites.

Sufficient sample size (considered to be ≥ 9 fish per species for this study) was only available at four reservoirs to adequately estimate exposure and risk for a given species. Those site/species combinations with sufficient sample size were spotted bass at Camp Far West Reservoir (n = 14), largemouth bass at Lake Combie (n = 9), smallmouth bass at Lake Englebright (n = 12), and channel catfish at Rollins Reservoir (n = 13). None of these samples were for the same species, making statistical comparisons among sites even more difficult. If all stream collection sites in the mining area were combined for each river or creek, three had adequate sample size for a single species. Those were rainbow trout along the Bear (n = 14) and South Yuba (n = 13) Rivers and brown trout along Deer Creek or its tributaries (n = 12). Ten brown trout were also collected as reference samples between two sites outside the mining areas along the South Yuba River and the Bear River. These two collection sites were combined in this evaluation but treated separately from fish collected in the mining areas of these rivers. Interpretation of data given the limited sample size is discussed in the exposure assessment, risk characterization, and guidelines sections of this document.

METHYLMERCURY TOXICOLOGY AND HAZARD IDENTIFICATION

The toxicity of mercury to humans is greatly dependent on its chemical form (elemental, inorganic, or organic) and route of exposure (oral, dermal, or inhalation). Methylmercury (an organic form) is highly toxic and can pose a variety of human health risks (NAS/NRC, 2000). Of the total amount of mercury found in fish muscle tissue, methylmercury comprises more than 95 percent (ATSDR, 1999; Bloom, 1992). Because analysis of total mercury is less expensive than that for methylmercury, total mercury is usually analyzed for most fish studies. In this study, total mercury was measured and assumed to be 100 percent methylmercury for the purposes of risk assessment.

Fish consumption accounts for almost 100 percent of the average daily methylmercury intake in adults not occupationally exposed to this chemical (ATSDR, 1999). As noted above, almost all fish contain detectable levels of methylmercury, which, when ingested, is almost completely absorbed from the gastrointestinal tract (Aberg et al., 1969; Myers et al., 2000). Once absorbed, methylmercury is distributed throughout the body, reaching the largest concentration in kidneys. Its ability to cross the placenta as well as the blood brain barrier allows methylmercury to accumulate in the brain and fetus, which are known to be especially sensitive to the toxic effects of this chemical (ATSDR, 1999). In the body, methylmercury is slowly converted to inorganic mercury and excreted predominantly by the fecal (biliary) pathway. Methylmercury is also excreted in breast milk (ATSDR, 1999). The biological half-life of methylmercury is approximately 44-74 days in humans (Aberg, 1969; Smith et al., 1994), meaning that it takes approximately 44-74 days for one-half of an ingested dose of methylmercury to be eliminated from the body.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan) (Elhassani, 1982-83). The first mass methylmercury poisoning occurred in the 1950s and 1960s in Minamata, Japan, following the consumption of fish contaminated by industrial pollution (Marsh, 1987). The resulting illness was manifested largely by neurological signs such as loss of sensation in the hands and feet, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir et al., 1973; Marsh, 1987). This syndrome was subsequently named Minamata Disease. A second outbreak of methylmercury poisoning occurred in Niigata, Japan, in the mid-1960s. In that case, contaminated fish were also the source of illness (Marsh, 1987). In all, more than 2,000 cases of methylmercury poisoning were reported in Japan, including more than 900 deaths (Mishima, 1992).

The largest outbreak of methylmercury poisoning occurred in Iraq in 1971-1972 and resulted from consumption of bread made from seed grain treated with a methylmercury fungicide (Bakir et al., 1973). This epidemic occurred over a relatively short term (several months) compared to the Japanese outbreak. The mean methylmercury concentration of wheat flour samples was found to be 9.1 µg/g. Over 6,500 people were hospitalized, with 459 fatalities. Signs and symptoms of methylmercury toxicity were similar to those reported in the Japanese epidemic.

Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). When maternal methylmercury consumption is very high, as happened in Japan and Iraq, significant methylmercury toxicity can occur to the fetus during pregnancy, with only very mild or even in the absence of symptoms in the mother. In those cases, symptoms in children are often not recognized until development of cerebral palsy and/or mental retardation many months after birth (Harada, 1978; Marsh et al., 1980; Marsh et al., 1987; Matsumoto et al., 1964; Snyder, 1971).

The International Agency for Research on Cancer (IARC) has listed methylmercury compounds as possible human carcinogens, based on increased incidence of tumors in mice exposed to methylmercury chloride (IARC, 1993). Based on IARC's actions, OEHHA has administratively listed methylmercury compounds on the Proposition 65 list of carcinogens. A cancer potency factor (an estimate of the increased cancer risk from lifetime exposure to a chemical) has not yet been developed for methylmercury.

DOSE-RESPONSE ASSESSMENT FOR METHYLMERCURY

A reference dose (RfD) is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), expressed in units of mg/kg-day (IRIS, 1995). This estimate includes a safety factor to account for data uncertainty. The underlying assumption of a reference dose is that, unlike carcinogenic effects, there is a threshold dose below which certain toxic effects will not occur. The reference dose for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals and/or humans. These studies are used to determine a No-Observed-Adverse-Effect-Level (NOAEL; the highest dose at which no adverse effect is seen), a Lowest-Observed-Adverse-Effect-Level (LOAEL; the lowest dose at which any adverse effect is seen), or a benchmark dose level (BMDL; a statistical lower confidence limit of a dose that produces a certain percent change in the risk of an adverse effect) (IRIS, 1995). Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, a reference dose is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the possibility of adverse effects occurring has increased (IRIS, 1993).

The first U.S. EPA RfD for methylmercury was developed in 1985 and set at 3×10^{-4} mg/kg-day (U.S. EPA, 1997). This RfD was based, in part, on a World Health Organization report summarizing data obtained from several early epidemiological studies on the Iraqi and Japanese methylmercury poisoning outbreaks (WHO, 1976). WHO found that the earliest symptoms of methylmercury intoxication (paresthesias) were reported in these studies at blood and hair concentrations ranging from 200-500 μg/L and 50-125 μg/g in adults, respectively. In cases where ingested mercury dose could be estimated (based, for example, on bread mercury concentration and number of loaves consumed daily), an empirical correlation between blood and/or hair mercury concentrations and onset of symptoms was obtained. From these studies, WHO determined that methylmercury exposure equivalent to long-term daily intake of 3-7 μg/kg body weight in adults was associated with an approximately 5 percent prevalence of paresthesias (WHO, 1976). U.S. EPA further cited a study by Clarkson et al. (1976) to support the range of mercury concentrations at which paresthesias are first observed in sensitive members of the adult population. This study found that a small percentage of Iraqi adults exposed to methylmercury-treated seed grain developed paresthesias at blood levels ranging from 240 to 480 μg/L. U.S. EPA applied a 10-fold uncertainty factor to the LOAEL (3 μg/kg-day) to reach what was expected to be the NOAEL. Because the LOAEL was observed in sensitive individuals in the population after chronic exposure, additional uncertainty factors were not considered necessary for exposed adults (U.S. EPA, 1997).

Although this RfD was derived based on effects in adults, even at that time researchers were aware that the fetus might be more sensitive to methylmercury (WHO, 1976). It was not until 1995, however, that U.S. EPA had sufficient data from Marsh et al. (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). Marsh et al. (1987) collected and summarized data from 81 mother and child pairs where the child had been exposed to methylmercury *in utero* during the Iraqi epidemic. Maximum mercury concentrations in maternal hair during gestation were correlated with clinical signs in the offspring such as cerebral palsy, altered muscle tone and deep tendon reflexes, and delayed developmental milestones that were observed over a period of several years after the poisoning. Clinical effects incidence tables included in the critique of the risk assessment for methylmercury conducted by U.S. FDA (Seafood Safety, 1991) provided dose-response data for a benchmark dose approach to the RfD, rather than the previously used NOAEL/LOAEL method. The BMDL was based on a maternal hair mercury concentration of 11 ppm. From that, an average blood mercury concentration of 44 μg/L was estimated based on a hair: blood concentration ratio of 250:1. Blood mercury concentration was, in turn, used to calculate a daily oral dose of 1.1 μg/kg-day, using an equation that assumed steady-state conditions and first-order kinetics for mercury. An uncertainty factor of 10 was applied to this dose to account for variability in the biological half-life of methylmercury, the lack of a two-generation reproductive study and insufficient data on the effects of exposure duration on developmental neurotoxicity and adult paresthesia. The oral RfD was then calculated to be 1×10^{-4} mg/kg-day, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

The two previous RfDs for methylmercury were developed using data from high-dose poisoning events. Recently, the National Academy of Sciences was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NAS/NRC, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in the Seychelles Islands (Davidson et al., 1995, 1998), the Faroe Islands (Grandjean et al., 1997, 1998, 1999), and New Zealand (Kjellstrom et al., 1986, 1989). The residents of these areas were selected for study because their diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NAS/NRC, 2000).

Although estimated prenatal methylmercury exposures were similar among the three studies, subtle neurobehavioral effects in children were found to be associated with maternal methylmercury dose in the Faroe Islands and New Zealand studies, but not in the Seychelle Islands study. The reasons for this discrepancy were unclear; however, it may have resulted from differences in sources of exposure (marine mammals and/or fish), differences in exposure pattern, differences in neurobehavioral tests administered and age at testing, the effects of confounding variables, or issues of statistical analysis (NRC/NAS, 2000). After review of these studies, the National Academy of Sciences report supported the current U.S. EPA RfD of $1x10^{-4}$ mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data. U.S. EPA has recently published a new RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). In order to develop an RfD, U.S. EPA used several scores from the Faroes data, rather than a single measure for the critical endpoint, as is customary (IRIS, 2001). U.S. EPA developed BMDLs utilizing test scores for several different neuropsychological effects and the preferred biomarker for the Faroes data (cord blood). The BMDLs for different neuropsychological effects in the Faroes study ranged from 46-79 ppb mercury. U.S. EPA then chose a one-compartment model for conversion of cord blood to ingested maternal dose, which resulted in estimated maternal mercury exposures of 0.857-1.472 µg/kg-day (IRIS, 2001). An uncertainty factor of ten was applied to the oral doses corresponding to the range of BMDLs to account for interindividual toxicokinetic variability in ingested dose estimation from cord-blood mercury levels and pharmacodynamic variability and uncertainty, leading to an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). In support of this RfD, U.S. EPA found that benchmark dose analysis of several neuropsychological endpoints from the Faroe Island and New Zealand studies, as well as an integrative analysis of all three epidemiological studies, converged on an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). U.S. EPA uses this RfD for all populations.

OEHHA finds that there is convincing evidence that the fetus is more sensitive than adults to the neurotoxic and subtle neuropsychological effects of methylmercury. As noted previously, during the Japanese and Iraqi methylmercury poisoning outbreaks, significant neurological toxicity occurred to the fetus even in the absence of symptoms in the mother. In later epidemiological studies at lower exposure levels (e.g., in the Faroe Islands), these differences in maternal and fetal susceptibility to methylmercury toxicity were also observed. Recent evidence has shown that the nervous system continues to develop through adolescence (see, for example, Giedd et al., 1999; Paus et al., 1999; Rice and Barone, 2000). As such, it is likely that exposure to a neurotoxic agent during this time may damage neural structure and function (Adams et al., 2000), which may not become evident for many years (Rice and Barone, 2000). Thus, OEHHA considers the RfD based on subtle neuropsychological effects following fetal exposure to be the best estimate of a protective daily exposure level for pregnant or nursing females and children aged 17 years and younger.

OEHHA also recognizes that fish can play an important role in a healthy diet, particularly when it replaces other, higher fat sources of protein. Numerous human and animal studies have shown that fish oils have beneficial cardiovascular and neurological effects (see, for example, Harris and Isley, 2001; Iso et al., 2001; Mori and Beilin et al., 2001; Daviglus et al., 1997; von Schacky et al., 1999; Valagussa et al., 1999; Moriguchi et al., 2000; Lim and Suzuki, 2000). Nonetheless, the hazards of methylmercury that may be present in fish, particularly to developing fetuses and children, cannot be overlooked. When contaminants are present in a specific medium (e.g., a food) that can be differentially avoided, it is not necessary to treat all populations in the most conservative manner to protect the most sensitive population. Sport fish consumption advisories are such a case. Exposure advice can be tailored to specific risks and benefits for populations with different susceptibilities so that each population is protected without undue burden to the other. Fish consumption advisories utilize the best scientific data available to provide the most relevant advice and protection for all potential consumers.

In an effort to balance the risks of methylmercury contamination in different populations with the cardiovascular and neurological benefits of fish consumption, two separate RfDs will be used to assess risk for different population groups. OEHHA has formerly used separate methylmercury RfDs for adults and pregnant females to formulate advisories for methylmercury contamination of sport fish (Stratton et al., 1987). Additionally, the majority of states issue separate consumption advice for sensitive (e.g., children) and general population groups. Thus, the U.S. EPA RfD of $1x10^{-4}$ mg/kg-day based on the Faroe Island data will be used in this advisory for females of childbearing age and children aged 17 and younger. An RfD of $3x10^{-4}$ mg/kg-day will be used for females beyond their childbearing years and adult males.

EXPOSURE ASSESSMENT FOR EATING SPORT FISH FROM THE SIERRA LAKES REGION

An exposure assessment is the qualitative or quantitative estimation of the magnitude, frequency, duration, and route of exposure to a chemical and is generally expressed as intake in mg/kg-day (U.S. EPA, 1989). For the Sierra Lakes project, the exposure assessment estimated methylmercury exposure that would be anticipated for sport fish consumers under different conditions (e.g., eating different fish). Fish consumption rates were combined with the level of mercury in fish in order to predict the likely human exposure to mercury from this source. Because, as already noted, the primary route of exposure to methylmercury in the United States is via consumption of finfish (U.S. EPA, 1997), especially for sport fishers, fish consumption was the only exposure route to methylmercury considered in this exposure assessment.

Fish Consumption Data

Fish consumption rates (g or kg fish/day) can be estimated from national or local consumption studies and are used to calculate likely human exposures to contaminants in fish. Over 1,200 recreational anglers were interviewed regarding their fish consumption patterns in a large study conducted in the Santa Monica Bay area (SCCWRP, 1994). Because sport fish consumption rates of marine fishers have been shown to be similar to the consumption rates of freshwater fishers (Gassel, 2001), these data were used to estimate fish consumption rates for other water bodies in California, including the Sierra Lakes region.

Typically, two consumption estimates are used in exposure calculations to assess fish intake in varying population groups: a mean or median value representing the central tendency of fish intake, and an upper percentile (90-99 percent) representing a high fish intake. The median consumption rate is the 50th percentile for any study, and represents the level at which half of the population consumes more and half of the population consumes less. This measure of central tendency has been selected for exposure assessments when using a single-species diet exposure scenario. OEHHA used the median fish consumption rate reported in the Santa Monica Bay study of 21 g/day (0.021 kg/day) (SCCWRP, 1994). This is equivalent to consuming just less than three standard (eight ounce) meals per month of sport fish. To represent high-level consumers, the 90th percentile was chosen to estimate fish consumption using a single-species diet scenario. Most consumers do not eat just one fish species, so their risk from consuming the most contaminated species is mitigated by consumption of less contaminated fish. Combining contamination data for the most contaminated fish with the highest possible consumption rate (the 99th percentile) would clearly overestimate risk for virtually all consumers. Thus, the 90th percentile consumption rate was used in this report. In the Santa Monica Bay study, this rate was 107 g/day (0.107 kg/day) or approximately 14 meals of sport fish per month.

Exposure calculations are based on a mg/kg-day basis (i.e., mg of chemical per kg of body weight per day) (U.S. EPA, 1989). In risk assessment, a body weight of 70 kg is generally used to represent a typical adult weight. The daily human exposure to methylmercury from fish consumption can be calculated with the following formula:

$$\text{mg methylmercury/kg-day} = \frac{\text{(mg methylmercury/kg fish)(kg fish/day)}}{\text{70 kg body weight}}$$

For individuals weighing more or less than 70 kg, it is assumed that their consumption rates will be proportionately higher or lower, respectively, yielding an overall similar exposure level following consumption of equally contaminated fish.

Mercury Contamination Data

In any survey of multiple species over a fairly wide geographic area, one would anticipate large variations in mercury content. In general, mercury concentrations in fish and other biota are dependent on the mercury level of the environment in which they reside. However, there are many factors that affect the accumulation of mercury in fish tissue. Fish species and age (as inferred from length) are known to be important determinants of tissue mercury concentration (WHO, 1989; 1990). Fish at the highest trophic levels (i.e., predatory fish) generally have the highest levels of mercury. Additionally, because the biological half-life of methylmercury in fish is much longer (approximately 2 years) than in mammals, tissue concentrations increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). Thus, with increasing age (length) within a given species, tissue methylmercury concentrations are expected to increase. In addition to differences in species, size, and water mercury concentration, the accumulation of mercury in fish is also dependent on environmental differences in pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology in individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989). Fish collected for the Sierra Lakes study would be anticipated to differ widely in their mercury concentration based on numerous differences in these variables among water bodies.

The mean mercury concentration, length, and sample size for each species for all Sierra Lakes sites combined are presented in Table 1. Mean mercury concentrations for each species by water body are presented in Tables 2 (lakes and reservoirs) and 3 (rivers, streams, and creeks). Complete descriptive statistics for fish in this study can be found in Appendix 1. Only legal and/or edible size fish were included in all analyses (≥305 and ≥195 mm total length for bass and trout, respectively). The distribution of mercury concentrations in each fish species collected was tested for normality. For those species with sufficient sample size to test, the mercury concentration was normally distributed in some species (bluegill, channel catfish and spotted bass), but not in others (brown trout, largemouth bass, smallmouth bass, and rainbow trout). Transformation of the data did not significantly improve the results or interpretation of additional statistical analyses. Thus, arithmetic means, rather than geometric means, were used to represent the central tendency (average) of mercury concentrations for all species in this report. In general, arithmetic means for environmental chemical exposures are more health-protective than geometric means and are commonly used in human health risk assessments.

As noted in the background section, for most species at the majority of sites, sample size was not adequate to perform a standard exposure assessment and risk characterization or to make statistical comparisons of fish mercury concentrations among sites. Nonetheless, a general review of the data showed that some trends were apparent. For example, species differences in mercury content were evident at some sites. As expected, piscivorous (predatory) fish such as smallmouth, largemouth and spotted bass had the highest mercury concentrations compared to other species. With the exception of channel catfish, these fish also had the longest mean lengths. Some site differences in fish mercury concentrations were also noted. Fish with the highest mercury levels tended to be found at Camp Far West Reservoir and Lake Combie. Additionally, brown trout appeared to have higher mercury concentrations when caught from stream sites compared to reservoirs. This may have reflected the higher probability that trout caught in reservoirs were stocked, thus having lower residence time in affected waters. Because all fish species were not collected equally among reservoirs or stream sites, however, it was difficult to draw strong conclusions from these data.

In deciding how to analyze and interpret the contamination data for each species and site, sample size was the primary factor considered in determining whether it was appropriate to perform an exposure assessment and risk characterization on that species and site in this report. Each reservoir was treated as a separate site; stream collection sites were combined for mining areas of the Bear River, South Yuba River and Deer Creek sites, respectively, and treated as three individual sites. The reference (non-mining) areas of the Bear River and South Yuba River were combined and treated as one site. Additional supporting information was considered to develop consumption guidelines for some species at some sites. Because of extremely small sample size, black crappie and green sunfish were not evaluated further.

Camp Far West Reservoir

A total of 23 fish were caught and analyzed for mercury content at Camp Far West Reservoir. This included five bluegill (analyzed as two single samples and one composite of three samples), three channel catfish, one largemouth bass, and 14 spotted bass. The bluegill samples ranged in length from 159 to 175 mm, with a weighted mean length of 169 mm. Weighted mean mercury concentration for this species was 0.25 ppm, with a range of 0.22 to 0.34 ppm. The overall mean mercury concentration for channel catfish at this site was 0.63 ppm, with a mean length of 461 mm. The largemouth bass was 387 mm in length with a mercury concentration of 0.81 ppm. The spotted bass had a mean mercury concentration of 0.96 ppm, with a range of 0.58 to 1.53 ppm. The mean length of spotted bass was 367 mm, ranging from 315 to 455 mm. Because a minimum sample size of three composites or nine individual fish was only obtained for spotted bass at this reservoir, that is the only species for which an exposure assessment was conducted.

Lake Combie

A total of 13 fish were collected and analyzed from Lake Combie. Two bluegill had a mean mercury concentration of 0.18 ppm and a mean length of 135 mm. Two rainbow trout contained an average of 0.13 ppm mercury and averaged 263 mm in length. Nine largemouth bass were collected from the lake and averaged 0.90-ppm mercury (range: 0.74-1.18), with a mean length of 379 mm. Because of inadequate sample size for other species, only largemouth bass were considered in the exposure assessment for this site.

Lake Englebright

Sixteen legal-sized fish were analyzed from Lake Englebright, including 12 legal-sized smallmouth bass, one legal-sized largemouth bass, and three spotted bass. The smallmouth bass ranged in length from 305 to 358 mm, with a mean of 323 mm. Mercury concentration of smallmouth bass ranged from 0.50 to 0.96 ppm, with a mean of 0.66 ppm. The largemouth bass was 312 mm in length with a mercury concentration of 0.27 ppm. Three spotted bass had a mean mercury content of 0.36 ppm (range: 0.34 to 0.38 ppm) and a mean length of 343 mm (range: 317 to 360 mm). Because the minimum recommended sample size was only collected for smallmouth bass, only that species was used in the exposure assessment for Lake Englebright.

Rollins Reservoir

Twenty-five legal-sized fish were collected and analyzed for mercury content from Rollins Reservoir. Two composites and one individual sample of bluegill were collected (seven total fish) and had a weighted mean mercury concentration of 0.22 ppm, and a weighted mean length of 164 mm. Four brown trout were analyzed; the mean mercury concentration was 0.06 ppm, with a range of 0.02 to 0.09 ppm. The length of brown trout ranged from 269 to 292 mm, with a mean of 282 mm. Thirteen channel catfish were collected. The mean mercury concentration for this species was 0.36 ppm, with a range of 0.16 to 0.51 ppm. Length ranged from 434 mm to 625 mm, with a mean of 535 mm. Only one largemouth bass collected from this lake was of legal size; the mercury concentration and length of this fish were 0.44 ppm and 347 mm, respectively. For Rollins Reservoir, only catfish were collected in sufficient numbers for use in an exposure assessment.

Scotts Flat Reservoir

Two bluegill, two brown trout and seven largemouth bass were collected at Scotts Flat Reservoir. Bluegill had a mean mercury concentration of 0.09 ppm, with a mean length of 165 mm. Brown trout had a mean mercury concentration of 0.11 ppm and a mean length of 372 mm. The mean mercury content of largemouth bass was 0.38 ppm (range: 0.20 to 0.48) and the mean length was 362 mm (range: 334 to 400 mm). Because a sample size of nine individual fish or three composites with a minimum of three fish per composite was not collected for any species, an exposure assessment was not conducted for this reservoir.

The Bear River

Four brown trout were collected from mining area sites along the Bear River and its tributaries. The mean mercury concentration in these fish was 0.28 ppm, with a range of 0.06 to 0.43. The mean length of brown trout was 360 mm. Four brown trout were also collected along the Bear River outside the historic mining area. The mean concentration for those brown trout was 0.07 ppm, with a range of 0.05 to 0.10 ppm. Mean length was 261 mm (range: 193 to 270). Fourteen rainbow trout (≥ 195 mm in length) were collected from the mining region of the Bear River and analyzed as eight individual samples and two composites of three fish per composite. The weighted mean mercury concentration was 0.16 ppm. The range of mercury values in rainbow trout was 0.06 to 0.38 ppm. The mean length of these fish was 234 mm, with a range of 210 to 301 mm. Because sample size was sufficient only in this species, rainbow trout were used in the exposure assessment for the Bear River.

Deer Creek

A total of 13 fish were collected from two sites along Deer Creek, including 12 brown trout and one rainbow trout. Brown trout had a mean mercury concentration of 0.24 ppm, with a range of 0.06 to 0.39 ppm. The single rainbow trout contained 0.22 ppm mercury and was 270 mm in length. Twelve brown trout were used in the exposure assessment for this water body.

South Yuba River

Four individual samples of rainbow trout as well as three composites of three individuals per sample were collected from mining areas along the South Yuba River (for a total 13 fish). The weighted mean mercury content was 0.17 ppm and the weighted mean length was 211 mm. Six brown trout were also analyzed from outside the mining region of the South Yuba River. Mercury content averaged 0.05 ppm (range: 0.04 to 0.06 ppm) while mean length was 223 mm (range: 193 to 270 mm). An exposure assessment was conducted only for rainbow trout in the mining region of the South Yuba River.

Using mercury concentrations for each statistically valid species and site combination described above, daily mercury exposures at different levels of fish consumption are presented in Table 4 for 70 kg adults. The lowest exposure resulted from consumption of 21 g/day of rainbow trout from sites along the Bear River; the highest exposure followed consumption of 107 g/day of spotted bass at Camp Far West Reservoir.

RISK CHARACTERIZATION OF EATING SPORT FISH FROM THE SIERRA LAKES REGION

In order to calculate potential adverse effects from exposure to hazardous substances, intake estimates developed during the exposure assessment must be compared to toxicity values using the formula E/RfD, where E equals the exposure level (intake) and RfD equals the reference dose (U.S. EPA, 1989). This ratio is called the hazard quotient (HQ). If the HQ is less than unity (i.e., intake is less than the RfD), it is considered unlikely that even sensitive subpopulations will experience adverse health effects from this chemical exposure. If the HQ is greater than unity (intake is greater than the RfD), there is increasing risk of negative health effects, particularly when exposure is a multiple of the RfD (U.S. EPA, 1989).

As noted above, of the nine fish species collected from 19 different sites, in only seven cases was the sample size adequate (determined to be $n \geq 9$ for this study) to be reasonably confident that measured levels were accurate representations of the true mercury concentrations in those species and water bodies. Potential hazards or risks associated with consuming fish species are generally calculated separately as though people only consume one species of fish. In actuality, this is often not the case; however, it does serve to show which species contributes most to potential health risks.

Using the exposure doses for each of the mining area species/site combinations presented in Table 4, HQs for methylmercury at different levels of fish consumption for females of childbearing age and children aged 17 and younger are shown in Table 5. The HQs were derived using the current U.S. EPA RfD for methylmercury of 1×10^{-4} mg/kg-day. HQs for brown trout and rainbow trout were less than unity (one) at the low-level (21 g/day) consumption rate for sites along Deer Creek (brown trout) and the Bear River and South Yuba River (rainbow trout). At the high-level (107 g/day) consumption rate, HQs were 2.45 and 2.6 for rainbow trout from the Bear River and South Yuba Rivers, respectively, and 3.67 for brown trout from Deer Creek. HQs for channel catfish, smallmouth, largemouth, and spotted bass were greater than unity (1.0) at the low-level and high-level consumption rates for sites where data were considered sufficient to make an evaluation. These included Rollins Reservoir for channel catfish, Lake Englebright for smallmouth bass, Lake Combie for largemouth bass, and Camp Far West Reservoir for spotted bass. At the low-level consumption rate, the HQ approached 3.0 for largemouth bass at Lake Combie and spotted bass at Camp Far West and 2.0 for smallmouth bass at Lake Englebright. At the high-level consumption rate, the HQ was 5.5 for channel catfish at Rollins Reservoir. For high-level consumers, the HQ ranged from approximately ten to nearly 15 for these three bass species at these three sites. The highest HQ (14.67) resulted from high-level consumption of spotted bass at Camp Far West Reservoir.

Using the exposure doses for each of the mining area species/site combinations presented in Table 4, HQs for methylmercury at different levels of fish consumption for females beyond their childbearing years and adult males are shown in Table 6. HQs were derived using the adult U.S. EPA RfD for methylmercury of 3×10^{-4} mg/kg-day. For brown trout from Deer Creek, HQs only exceeded one (1.22) at the higher consumption rate (107 g/day). HQs did not exceed 1.0 at either consumption rate for rainbow trout taken from the Bear River or South Yuba River. For channel catfish at Rollins Reservoir, the HQ only exceeded one (1.8) at the higher consumption rate. At the lower consumption rate, HQs for largemouth bass at Lake Combie and spotted bass at Camp Far West Reservoir approached, but did not exceed, 1.0. At the higher consumption rate, HQs exceeded unity for all four species collected in sufficient quantities from lakes or reservoirs, ranging from 1.8 (channel catfish at Rollins Reservoir) to 4.89 (spotted bass at Camp Far West Reservoir).

Using the available Sierra Lakes data, consumption of spotted bass at Camp Far West Reservoir poses the greatest potential health hazard resulting from methylmercury exposure in the region.

For sensitive populations (females of childbearing age and children aged 17 and younger), HQs from eating spotted bass at this site suggest that even consumers eating only a few meals per month (averaging 21 g/day) are exposed to mercury at nearly three times the reference level. High-level consumers in this group (averaging 107 g/day) are exposed to mercury at almost 15 times the RfD. For females beyond their childbearing years and adult males, methylmercury exposure for this species and site is still nearly five times the RfD at the higher consumption rate.

For sensitive populations, the potential hazards associated with consumption of largemouth bass at Lake Combie are almost as high as that from spotted bass at Camp Far West Reservoir. Low-level consumers are exposed to methylmercury at nearly three times the RfD. High-level consumers eating largemouth bass at the average mercury concentration from this lake would be exposed to 14 times the reference level for this chemical. For females beyond their childbearing years and adult males, exposure only exceeded the RfD for high-level consumers of largemouth bass at this site, who would be exposed to nearly five times the RfD for methylmercury.

Ingestion of smallmouth bass from Lake Englebright also poses potential health hazards for sensitive populations. Low-level consumers are exposed to approximately twice the RfD, while high-level consumers are exposed to ten times the RfD for methylmercury. For females beyond their childbearing years and adult males, low-level consumers are not considered at risk of adverse health effects associated with methylmercury exposure; however, high-level consumers are exposed to over three times the RfD for methylmercury.

For sensitive populations, catfish from Rollins Reservoir had lower, but still significant, mercury levels with even low-level consumers slightly exceeding the RfD for this chemical. At high-level consumption, the RfD would be surpassed by 5.5 times. For females beyond their childbearing years and adult males, the RfD was slightly exceeded only for high-level consumers.

Consumption of brown trout from Deer Creek would not exceed the RfD for sensitive populations at the low-level consumption rate, but would exceed the RfD for high-level consumers by nearly four-fold. For females beyond their childbearing years and adult males, the HQ was slightly more than unity only for high-level consumers. The methylmercury RfD for sensitive populations would be exceeded only by high-level consumers of rainbow trout from the Bear or South Yuba Rivers (approximately 2.5-fold). For females beyond their childbearing years and adult males, consumption of rainbow trout from these sites did not exceed the RfD at either consumption rate.

Although the risk characterization suggests that there are potential hazards associated with consumption of some fish species at sites where the RfD is exceeded, it does not follow that consumers will show adverse effects from this consumption. The RfD incorporates a margin of safety to account for uncertainties in the data and differences among individuals. Of all consumers, those at greatest risk are females of childbearing age and children aged 17 and younger who frequently eat large amounts of bass or catfish from reservoirs in the Sierra Lakes area.

SUPPORTING DATA FOR DEVELOPING FISH CONSUMPTION GUIDELINES

Fish consumption guidelines are appropriate whenever there are sufficient data to suggest that adverse health effects may occur from unrestricted consumption of individual fish species at certain sites. Although the exposure assessment and risk characterization sections of this report utilized only data that were considered statistically valid for each species and site, other information may be useful to help develop additional recommendations. When there are less than nine individual or three composite samples at a site for a given species, data for that species may be extrapolated from other, similar species at that site or from the same species at a similar site to develop a weight-of-evidence approach. This method is acceptable when evaluation of the entire data set shows clear trends that justify the issuance of prudent, protective health advice even in the absence of a statistically representative sample. For example, it may be reasonable to provide consumption advice for a particular site/species combination with little or no data for that species (e.g., smallmouth and largemouth bass at Camp Far West Reservoir) when the mercury concentration in a similar species at that site (e.g., spotted bass) is significantly elevated.

For the Sierra Lakes area, supporting data were examined to determine whether, in an effort to be health protective, fish consumption advice could be offered even in cases where the sample size for an individual species at a specific site was less than nine fish. Supporting data were used in the following sequence: 1) contamination data for another closely related species at a similar trophic level available from the same site, and 2) contamination data for the same species available from a nearby site with similar hydrogeological and/or chemical contamination characteristics. When neither type of supporting data was available for a particular site/species combination, the U.S. EPA national freshwater sport fish consumption advice for pregnant or nursing women and young children was provided for these sensitive populations. OEHHA recommends that children through age 17 also follow this advice because of continued nervous system development through adolescence. For females beyond their childbearing years and adult males, the OEHHA general advice for sport fish consumption was given.

At Camp Far West Reservoir, an exposure and risk assessment was only conducted for spotted bass. However, chemical analysis of fish collected from this water body showed that they contain potentially harmful levels of mercury. As such, it was considered prudent to offer consumption guidance for other species. Because different species of bass often contain similar levels of the same contaminant, it is recommended that consumers follow the same advice for other bass species at Camp Far West as they do for spotted bass. Because only three catfish samples were obtained from Camp Far West Reservoir, it is recommended that consumers follow the channel catfish consumption advice for Rollins Reservoir (the only reservoir for which channel catfish data were sufficient for an evaluation).

At Lake Combie, only largemouth bass had sufficient sample size to conduct an exposure and risk assessment. However, similar to Camp Far West Reservoir, mercury levels in those fish were significantly elevated. Consequently, it is recommended that consumers follow the largemouth bass consumption advice for all other bass species at Lake Combie and the channel catfish advice for Rollins Reservoir.

At Lake Englebright, an exposure and risk assessment was only completed for smallmouth bass. It is recommended that fishers follow the consumption advice for smallmouth bass for all other bass species at Lake Englebright and the channel catfish advice for Rollins Reservoir.

Only channel catfish were collected in sufficient quantities to conduct an exposure and risk assessment at Rollins Reservoir. OEHHA recommends following the largemouth bass consumption advice at Lake Combie for all bass species at Rollins Reservoir as Lake Combie is the nearest water body to Rollins Reservoir and is located in the same watershed.

No species were collected in adequate numbers to conduct an exposure and risk assessment at Scotts Flat Reservoir. Additionally, no bass or catfish were collected in sufficient numbers at any other site in the Deer Creek Watershed to provide data for extrapolation to Scotts Flat Reservoir. As such, OEHHA recommends following the most common bass and channel catfish consumption advisories in the region (one and two meals per month, respectively, for females of childbearing age and children aged 17 and younger, and two and four meals per month, respectively, for females beyond their childbearing years and adult males) for bass and channel catfish at Scotts Flat Reservoir.

At the five reservoir sites, fish species other than bass and channel catfish were not analyzed in sufficient numbers at any site to conduct an exposure and risk assessment. For all other fish species at these sites, OEHHA recommends that females of childbearing age and children aged 17 and younger follow the U.S. EPA national sport fish consumption advice for pregnant or nursing women and young children or, for females beyond their childbearing years and adult males, the OEHHA general advice for sport fish consumption.

For mining areas of the Bear and South Yuba Rivers, OEHHA recommends following the rainbow trout advice for all other trout species. For Deer Creek, it is recommended to follow the consumption advice for brown trout for all other trout species. For all other fish species from river, stream, and creek sites, OEHHA recommends that females of childbearing age and children aged 17 and younger follow the U.S. EPA national sport fish consumption advice for pregnant or nursing women and young children or, for females beyond their childbearing years and adult males, the OEHHA general advice for sport fish consumption.

GUIDELINES FOR FISH CONSUMPTION

The risk characterization and evaluation of supporting data indicates that the HQ for methylmercury is consistently exceeded at typical consumption rates for numerous species and sites. Consumers should be informed of the potential hazards from eating fish from these areas, particularly those hazards relating to the developing fetus and children. All individuals, especially females of childbearing age and children aged 17 and younger, are advised to limit their fish consumption to reduce methylmercury ingestion to a level near the RfD.

Guidance tissue levels have been developed that relate the number and size of recommended fish meals to methylmercury concentrations found in fish (Table 7). OEHHA has developed guidance levels (Brodberg, 2000) similar to risk-based consumption limits recommended by U.S. EPA (U.S. EPA, 2000b). These guidance values were designed so that individuals consuming no more than a preset number of meals should not exceed the RfD for methylmercury. Meal sizes are based on a standard 8-ounce (227 g) portion of uncooked fish (approximately 6 ounces after cooking) for adults who weigh approximately 70 kg or 154 lbs. OEHHA's general advice allows fishers to consume up to twelve meals per month without exceeding the reference dose for a specific contaminant (e.g., mercury). Twelve meals per month (i.e., the general advice consumption level) is representative of an upper bound consumption rate for frequent sport fish consumers in California (Gassel, 2001). OEHHA begins issuing site specific consumption advice if data indicate that consumption of twelve meals per month is potentially hazardous. This advice begins for sensitive populations when the methylmercury concentration exceeds 0.08 ppm. Tissue guidance levels for females beyond their childbearing years and adult males are approximately three times higher than for sensitive populations because of the 3-fold higher RfD level.

It is very important to note that guidance values are based on consumption of only one fish species. If an individual consumes multiple species or catches fish from more than one site, the recommended guidelines for different species and locations should not be combined. For example, if a person eats a meal of fish from the meal per month category, he or she should not eat another fish species at any site where there is a fish consumption advisory for that species for at least one month.

Based on the evaluation of all data from the Sierra Lakes region, it is recommended that sport fish consumers follow the separate advisories that OEHHA has developed for black bass species (largemouth, smallmouth and spotted bass) and channel catfish for the following five reservoirs in the Sierra Lakes region: Camp Far West Reservoir, Lake Combie, Lake Englebright, Rollins Reservoir and Scotts Flat Reservoir. Additionally, consumers should follow the advisories to limit consumption of trout species for sections of the Bear River, South Yuba River and Deer Creek. Specifically, females of childbearing age and children aged 17 and younger should eat no bass from Camp Far West Reservoir. Additionally, they should eat no more than two meals per month of channel catfish from that site. At Lake Combie, Lake Englebright, Rollins Reservoir, and Scotts Flat Reservoir, consumption of bass and channel catfish should be restricted for this group to no more than one or two meals per month for these species, respectively. No more than two meals per month of any trout species should be consumed from Deer Creek or no more than four meals per month of any trout species from mining areas of the Bear and South Yuba Rivers. For other fish in reservoirs or streams in this region and throughout California, it is recommended that females of childbearing age and children aged 17 and younger follow the recent U.S. EPA national freshwater sport fish consumption advice for pregnant or nursing women and young children of no more than four meals per month of fresh water fish (U.S. EPA, 2001).

OEHHA also recommends that females of childbearing age and children aged 17 and younger follow the FDA advice for pregnant women, women of childbearing age who may become pregnant, nursing mothers, and young children on commercial fish consumption. FDA advises these individuals not to eat shark, swordfish, king mackerel, or tilefish because of their high levels of mercury. FDA also recommends that these women can safely eat up to an average of 12 ounces per week of other cooked fish from a store or restaurant such as shellfish, canned fish, smaller ocean fish or farm-raised fish. Children should limit consumption to less than 12 ounces of cooked fish per week. Also, if 12 ounces of cooked fish from a store or restaurant are eaten in a given week, then sport fish caught in the Sierra Lakes region should not be eaten in the same week.

For the females beyond their childbearing years and adult males, OEHHA recommends that bass from Camp Far West Reservoir be consumed no more than two times per month. Additionally, consumption of channel catfish from this reservoir should be limited to no more than four meals per month. Consumption of all bass and channel catfish from Lake Combie, Rollins Reservoir, and Scotts Flat Reservoir should be restricted to no more than two or four meals per month for these species, respectively. Consumption of all bass and channel catfish from Lake Englebright should be limited to no more than four meals per month. Additionally, no more than four meals per month of any trout species should be consumed from Deer Creek or no more than twelve meals per month of any trout species from mining areas of the Bear and South Yuba Rivers. Because of the general pattern of mercury contamination in all fish sampled from the Sierra Lakes region, OEHHA advises that consumption of all other fish for which no site specific advice is given above be restricted to no more than 12 meals per month for females beyond their childbearing years and adult males from any of the above sites. Additionally, OEHHA recommends that females beyond their childbearing years and adult males take into account the commercial fish they eat, especially high-mercury fish such as shark, swordfish, king mackerel, or tilefish. If they consume these species, they should reduce consumption of sport fish caught in the Sierra Lakes region accordingly.

For general advice on how to limit your exposure to chemical contaminants in sport fish (e.g., eating smaller fish of legal size), see the California Sport Fish Consumption Advisories. It should be noted that, unlike the case for many fat-soluble organic contaminants (e.g., DDTs and PCBs), various cooking and cleaning techniques will not reduce the methylmercury content of fish. Meal sizes should be adjusted to body weight as described in this report on page 27.

FISH CONSUMPTION GUIDELINES FOR FEMALES OF CHILDBEARING AGE AND CHILDREN AGED 17 AND YOUNGER	
LOCATION AND FISH SPECIES	**DO NOT EAT MORE THAN***
	MEALS PER MONTH
Camp Far West Reservoir	
All Bass	**DO NOT EAT**
Channel Catfish	**2**
Lake Combie, Lake Englebright, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	**1**
Channel Catfish	**2**
Bear River below Highway 20, South Yuba River Below Lake Spalding	
All Trout	**4**
Deer Creek	
All Trout	**2**
All of the Above Sites**	
Other sport fish species	**4**

* Consumption limits for each species assume no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly.

**All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. If consumption advice is not available for that species at any site, follow U.S. EPA national guidance for pregnant or nursing women and young children recommending consumption of no more than one meal per week of freshwater sport fish.

Fish are nutritious and should be part of a healthy, balanced diet. As with many other kinds of food, however, it is prudent to consume fish in moderation. OEHHA provides this consumption advice to the public so that people can continue to eat fish without putting their health at risk.

FISH CONSUMPTION GUIDELINES FOR FEMALES BEYOND THEIR CHILDBEARING YEARS AND ADULT MALES

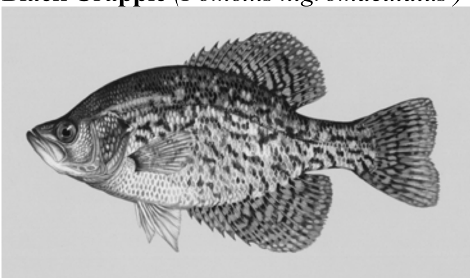
LOCATION AND FISH SPECIES	DO NOT EAT MORE THAN* MEALS PER MONTH
Camp Far West Reservoir	
All Bass	**2**
Channel Catfish	**4**
Lake Combie, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	**2**
Channel Catfish	**4**
Lake Englebright	
All Bass	**4**
Channel Catfish	**4**
Bear River below Highway 20, South Yuba River Below Lake Spalding	
All Trout	**12**
Deer Creek	
All Trout	**8**
All of the Above Sites**	
Other sport fish species	**12**

* Consumption limits for each species assume no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly.

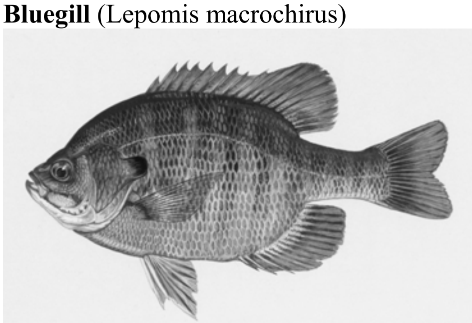
**All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. For fish species caught from the listed water bodies but not included in the guidelines, OEHHA recommends consumption of no more than 12 meals per month of any fresh water sport fish from the Sierra Lakes region.

Sierra Lakes Sport Fish

Black Crappie *(Pomoxis nigromaculatus)*

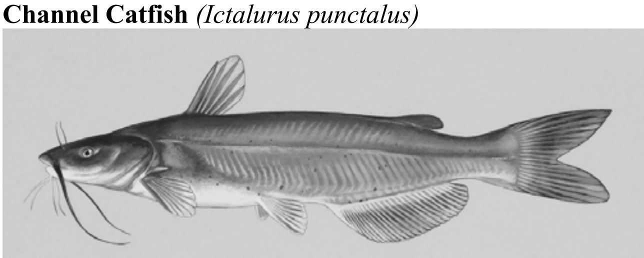


Bluegill (Lepomis macrochirus)

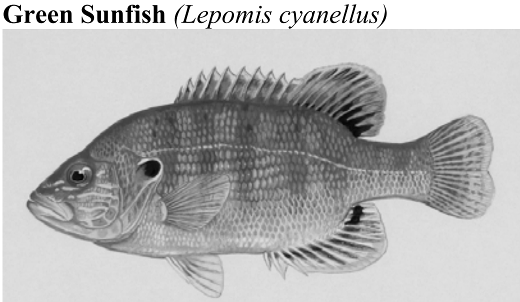


Brown Trout *(Salmo trutta)*

Channel Catfish *(Ictalurus punctalus)*

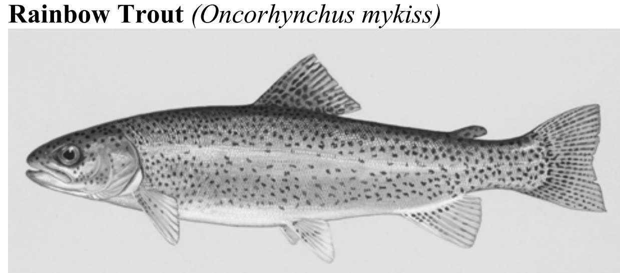


Green Sunfish *(Lepomis cyanellus)*

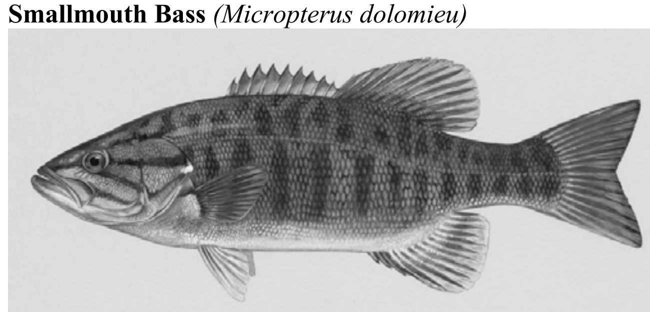


Largemouth Bass *(Micropterus salmoides)*

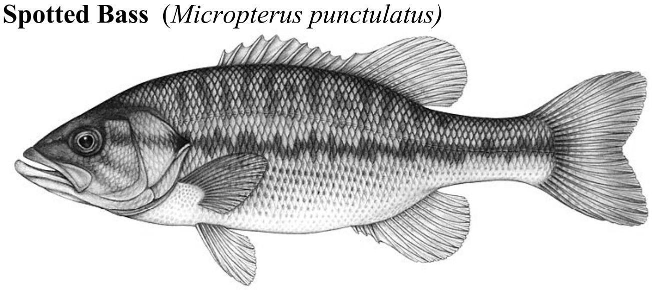
Rainbow Trout *(Oncorhynchus mykiss)*



Smallmouth Bass *(Micropterus dolomieu)*



Spotted Bass (*Micropterus punctulatus)*



Note: Pictures are not to scale.

ADJUSTING FISH MEAL SIZE FOR BODY WEIGHT

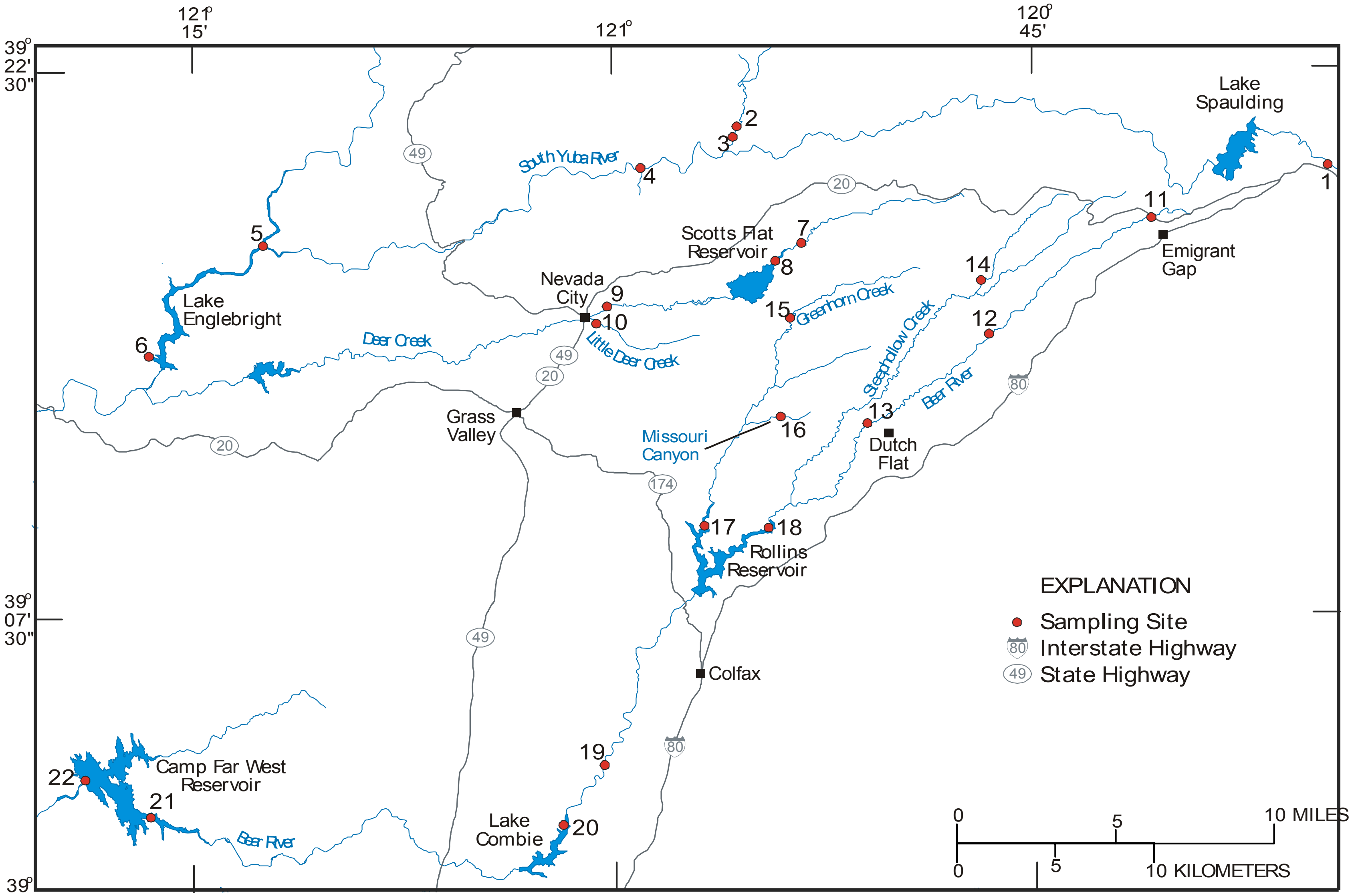
In the preceding site-specific guidance, OEHHA provides consumption advice in terms of meals for a given period (e.g., a meal per month), and uses an 8-ounce (prior to cooking) meal size as the standard amount allowed for the "average" adult. The average adult weights approximately 154 pounds (equivalent to 70 kg). Because you and your family members may weigh more or less than the average adult, you can use the chart below to adjust serving sizes to stay within the recommended consumption guidelines.

IF YOUR BODY WEIGHT IS…		**YOUR MEAL SIZE SHOULD NOT EXCEED…**	
Pounds	***or kilograms***	**Ounces**	***or grams***
19	9	1	28
39	18	2	57
58	26	3	85
77	35	4	113
96	44	5	142
116	53	6	170
135	61	7	199
154	70	8	227
173	79	9	255
193	88	10	284
212	96	11	312
≥231	≥105	12	340

RECOMMENDATIONS FOR FURTHER RESEARCH

The USGS reconnaissance survey did not collect adequate numbers of the multiple fish species caught and eaten by anglers in these water bodies for a complete human health evaluation at any site. It is recommended that further testing be done to more clearly elucidate mercury contamination problems in the area, with an emphasis on collecting data from Camp Far West Reservoir, Lake Combie, Deer Creek at Pioneer Park, and Bear River at Dog Bar Road. This is especially true for popular fish species that were not sampled or for fish for which there are not presently an adequate sample size. Table 8 lists recommended additional fish samples needed to conduct a comprehensive public health risk assessment for the Sierra Lakes area. Collection of additional data is recommended to provide anglers with full information on their potential risks and choices for fishing in this area.

Figure 1. Sampling sites for the Sierra Lakes study (from May et al., 2000)



Site Key

Site Number	Site Name
1	South Yuba River near Emigrant Gap
2	Humbug Creek above Falls
3	Humbug Creek below Falls
4	South Yuba River near Edwards Crossing
5	Lake Englebright (South Yuba arm)
6	Lake Englebright (Hogsback Ravine)
7	Deer Creek above Scotts Flat Reservoir
8	Scotts Flat Reservoir
9	Deer Creek near Willow Valley Road
10	Little Deer Creek at Pioneer Park
11	Bear River at Hwy 20
12	Bear River above Dutch Flat
13	Bear River below Dutch Flat
14	North Fork of Steephollow Creek
15	Greenhorn Creek above Buckeye Drain
16	Missouri Canyon
17	Rollins Reservoir (Greenhorn Creek arm)
18	Rollins Reservoir (Bear River arm)
19	Bear River at Dog Bar Road
20	Lake Combie
21	Camp Far West Reservoir (Bear River arm)
22	Camp Far West Reservoir (at dam)

Table 1. Overall Mean Mercury (Hg) Concentrations (ppm, wet weight) and Lengths (mm) of Fish from the Sierra Lakes Region[1]			
	Hg (ppm)	Length (mm)	Sample Size
Mining Sites			
Black Crappie	0.31	263	1[2]
Bluegill	0.20	162	10[3]
Brown Trout[4]	0.20	296	22
Rainbow Trout[5]	0.16	227	20[6]
Channel Catfish	0.41	521	16
Green Sunfish	0.12	175	3[7]
Smallmouth Bass[8]	0.66	323	12
Largemouth Bass[8]	0.65	368	19
Spotted Bass[8]	0.85	362	17
Reference Sites			
Brown Trout	0.06	238	10

[1]Weighted mean values were derived by weighting each chemical value reported by the lab (represented by a unique sample ID) by the number of individuals contained in the sample (composite or single fish).
[2]Includes 1 composite sample (3 individuals/sample).
[3]Includes 7 individual samples and 3 composite samples (3 individuals/sample).
[4]Excludes fish caught from reference sites.
[5]Excludes rainbow trout <195 mm.
[6]Includes 15 individual samples and 5 composite samples (3 individuals/sample).
[7]Includes 2 individual samples and 1 composite sample (3 individuals/sample).
[8]Includes only legal size bass (≥305 mm).

Table 2. Mean Mercury Concentrations (ppm, wet weight) (and sample size) in Fish from Five Sierra Lakes and Reservoirs[1]					
	Camp Far West Reservoir	Lake Combie	Lake Englebright	Rollins Reservoir	Scotts Flat Reservoir
Bluegill	0.25 (3)[2]	0.18 (2)	--	0.22 (3)[3]	0.09 (2)
Brown Trout	--	--	--	0.06 (4)	0.11 (2)
Rainbow Trout[4]	--	0.13 (2)	--	--	--
Channel Catfish	0.63 (3)	--	--	0.36 (13)	--
Smallmouth Bass[5]	--	--	0.66 (12)	--	--
Largemouth Bass[5]	0.81 (1)	0.90 (9)	0.27 (1)	0.44 (1)	0.38 (7)
Spotted Bass[5]	0.96 (14)	--	0.36 (3)	--	--

[1]Weighted mean values were derived by weighting each chemical value reported by the lab (represented by a unique sample ID) by the number of individuals contained in the sample (composite or single fish).
[2]Includes 2 single samples and 1 composite sample (3 individuals/sample).
[3]Includes 1 single sample and 2 composite samples (3 individuals/sample).
[4]Excludes rainbow trout <195 mm.
[5]Includes only legal size bass (≥ 305 mm).

Table 3. Mean Mercury Concentrations (ppm, wet weight) (and sample size) in Fish from Rivers, Streams and Creeks in the Sierra Lakes Region[1]			
	Bear River	Deer Creek	South Yuba River
Bluegill	--	--	--
Brown Trout[2]	.28 (4)[2]	.24 (12)	--[2]
Rainbow Trout[3]	.16 (10)[4]	.22 (1)	.17 (7)[5]
Channel Catfish	--	--	--
Smallmouth Bass[6]	--	--	--
Largemouth Bass[6]	--	--	--
Spotted Bass[6]	--	--	--

[1]Weighted mean values were derived by weighting each chemical value reported by the lab (represented by a unique sample ID) by the number of individuals contained in the sample (composite or single fish).
[2]Excludes reference sites.
[3]Excludes rainbow trout <195 mm.
[4]Includes 8 single samples and 2 composite samples (3 individuals/sample).
[5]Includes 4 single samples and 3 composite samples (3 individuals/sample).
[6]Includes only legal size bass (≥305 mm).

Table 4. Mercury (Hg) Concentrations (ppm, wet weight) and Exposure Dose (mg/kg-day) for Consumption of Fish from Selected Sierra Lakes Water Bodies

Species	Hg (ppm)	Daily Exposure (mg/kg-day)x10^{-4} (21 g/d CR)	Daily Exposure (mg/kg-day)x10^{-4} (107 g/d CR)
Brown Trout Deer Creek	0.24	0.72	3.67
Rainbow Trout Bear River	0.16	0.48	2.45
Rainbow Trout South Yuba River	0.17	0.51	2.6
Channel catfish Rollins Reservoir	0.36	1.08	5.5
Smallmouth bass Lake Englebright	0.66	1.98	10.09
Largemouth bass Lake Combie	0.90	2.70	13.76
Spotted bass Camp Far West Reservoir	0.96	2.88	14.67

Table 5. Methylmercury Hazard Quotient (HQ) Values for Consumption of Fish from Selected Sierra Lakes Water Bodies Using an RfD of $1x10^{-4}$ mg/kg-day		
Species	HQ (21 g/day consumption rate)	HQ (107 g/day consumption rate)
Brown Trout Deer Creek	0.72	3.67
Rainbow Trout Bear River	0.48	2.45
Rainbow Trout South Yuba River	0.51	2.6
Channel catfish Rollins Reservoir	1.08	5.5
Smallmouth bass Lake Englebright	1.98	10.09
Largemouth bass Lake Combie	2.70	13.76
Spotted bass Camp Far West Reservoir	2.88	14.67

Table 6. Methylmercury Hazard Quotient (HQ) Values for Consumption of Fish from Selected Sierra Lakes Water Bodies Using an RfD of $3x10^{-4}$ mg/kg-day		
Species	HQ (21 g/day consumption rate)	HQ (107 g/day consumption rate)
Brown Trout Deer Creek	0.24	1.22
Rainbow Trout Bear River	0.16	0.82
Rainbow Trout South Yuba River	0.17	0.87
Channel catfish Rollins Reservoir	0.36	1.8
Smallmouth bass Lake Englebright	0.66	3.36
Largemouth bass Lake Combie	0.9	4.59
Spotted bass Camp Far West Reservoir	0.96	4.89

Table 7. Guidance Tissue Levels (ppm Total Mercury or Methylmercury*, wet weight) for Two Population Groups						
	12 Meals/ Month* (90.0 g/day)	8 Meals/ Month (60.0 g/day)	4 Meals/ Month (30.0 g/day)	2 Meals/ Month (15.0 g/day)	1 Meal/ Month (7.5 g/day)	No Consumption
Females of childbearing age and children aged 17 and younger	≤ 0.08	>0.08-0.12	>0.12-0.23	>0.23-0.47	>0.47-0.93	>0.93
Females beyond their childbearing years and adult males	≤0.23	>0.23-0.35	>0.35-0.70	>0.70-1.40	>1.40-2.80	>2.80

*The values in this table are based on the assumption that 100% of total mercury measured in fish is methylmercury. This may not be true for shellfish, so methylmercury needs to be measured directly in these species for use in this table.

** OEHHA's general consumption advice protects fishers who eat up to twelve meals per month of sport fish. Twelve meals per month is representative of an upper bound consumption rate for frequent sport fish consumers in California (Gassel, 2001). OEHHA begins issuing site specific consumption advice if data indicate that consumption of twelve meals per month is potentially hazardous.

The recommended level for consumption of fish contaminated with a non-carcinogenic chemical such as methylmercury is below or equivalent to the chemical's reference level. People could eat more fish with a lower tissue concentration (before they exceed the reference level) than fish with a higher concentration. The following general equation can be used to calculate the fish tissue concentration (in mg/kg) at which the consumption exposure from a chemical with a non-carcinogenic effect is equal to the reference level for that chemical at any consumption level:

$$\text{Tissue concentration} = \frac{(\text{RfD mg/kg - day})(\text{kg Body Weight})(\text{RSC})}{\text{CR kg/day}}$$

where,

RfD	=	Chemical specific reference dose or other reference level
BW	=	Body weight of consumer
RSC	=	Relative source contribution of fish to total exposure
CR	=	Consumption rate as the daily amount of fish consumed

Table 7. Guidance Tissue Levels (ppm Total Mercury or Methylmercury*, wet weight) for Two Population Groups (continued)

This equation was applied above to determine tissue concentrations of methylmercury (assuming 100% of measured total mercury is methylmercury in fish) in sport fish that would be below or equivalent to the chemical's reference level when eating different amounts of fish. An RfD of $1x10^{-4}$ mg/kg-day was used for females of childbearing age and children aged 17 and younger. An RfD of $3x10^{-4}$ mg/kg-day was used for females beyond their childbearing years and adult males. A body weight of 70 kg was used to represent the average weight of an adult. It was assumed that fish represent 100 percent of the source of methylmercury to a fish consumer.

Meal Sizes used in this table:

Although people eat different meal sizes, their typical portion size is related to their individual body weight in a fairly consistent manner (see Table 6). The standard portion size eaten by an average adult (body weight 70 kg or 154 pounds) is eight ounces (227 g) (U.S. EPA, 1994). People tend to remember how many meals of a specific food they eat in a month and this interval is often used in consumption surveys (Gassel, 2001). A standard portion of one fish meal a month is equivalent to 7.5 $x10^{-3}$ kg/day, one meal per week is equivalent to 3.24 $x10^{-2}$ kg/day, and three meals per week is equivalent to 9.72 $x10^{-2}$ kg/day.

Table 8. Recommended Additional Fish Samples Needed to Conduct a Comprehensive Public Health Risk Assessment for the Sierra Lakes Region. Edible-/Legal-Size Fish Should be Sampled.								
	Site							
Species	**Camp Far West Reservoir**	**Lake Combie**	**Lake Englebright**	**Rollins Reservoir**	**Scotts Flat Reservoir**	**Bear River**	**Deer Creek**	**South Yuba River**
Bluegill	■	■	▲	■	■			
Green Sunfish	▲	▲	■	▲	■			
Black Crappie	■	▲	▲	■	▲			
Brown Trout	▲	▲	■	■	■	◆	◆	◆
Rainbow Trout	▲	■	■	■	■	◆	◆	◆
Channel Catfish	■	▲	▲	●	▲			
Smallmouth Bass	▲	▲	●	■	▲			
Largemouth Bass	■	●	■	■	■			
Spotted Bass	●	▲	■	▲	▲			
Striped Bass	■							
Carp	▲	▲	■	▲	▲			

■ Sample a minimum of 15 fish per water body.

● Sample a minimum of nine fish to confirm original data and measure inter-annual variation.

▲ Sample 9-15 individuals of these species when present in a water body.

◆ Trout species should be sampled at the same and additional sites in each river/creek system. Ideally 5 or more fish should be sampled at river/creek locations.

Appendix 1. Descriptive Statistics[1] for Mercury Concentration (ppm, wet weight) and Length (mm) of Fish From the Sierra Lakes Region

	Hg (ppm)						Length (mm)						Sample Size	
	Mean	Median	SD	Min	Max	CI[2]	Mean	Median	SD	Min	Max	CI[2]	Indiv	Composite (3 indiv/ sample)
Black crappie	.31						263						0	1
Bluegill	.20	.21	.08	.07	.41	.16-.25	162	161	15	125	193	154-170	7	3
Brown trout	.16	.10	.13	.02	.43	.11-.20	278	277	60	193	416	257-300	32	0
Mining Areas	.20	.16	.13	.02	.43	.14-.26	296	288	61	197	416	269-323	22	0
Deer Creek	.24	.25	.11	.06	.39	.17-.31	267	277	56	197	383	232-303	12	0
Non-Mining	.06	.06	.02	.04	.10	.05-.07	238	243	35	193	295	213-263	10	0
Rainbow trout (≥ 195 mm)	.16	.17	.06	.06	.38	.14-.19	227	213	31	195	301	215-239	15	5
Bear River	.16	.17	.09	.07	.38	.11-.21	234	220	29	210	301	217-251	8	2
South Yuba River	.17	.17	.02	.15	.22	.16-.18	211	200	24	195	270	196-226	4	3
Channel catfish	.41	.41	.15	.16	.75	.33-.49	521	528	53	434	625	493-549	16	0
Rollins Reservoir	.36	.38	.10	.16	.51	.30-.42	535	540	48	434	625	506-564	13	0
Green sunfish	.12	.13	.02	.08	.13	.09-.14	175	171	6	171	185	167-182	2	1
Largemouth bass (≥ 305mm)	.65	.74	.29	.20	1.18	.51-.79	368	370	34	312	435	352-384	19	0
Lake Combie	.90	.92	.14	.74	1.18	.80-1.01	379	388	36	324	435	352-407	9	0
Smallmouth bass (≥ 305 mm)	.66	.62	.14	.50	.96	.57-.75	323	314	17	305	358	312-333	12	0
Spotted bass (≥305mm)	.85	.80	.34	.34	1.53	.68-1.03	362	351	39	315	455	342-383	17	0

[1] Data weighted by number of individuals per sample.
[2] 95 percent Confidence Interval

Appendix 2. Interim Fish Consumption Notification for Placer, Nevada & Yuba Counties Consumption Recommendations

- Eating sport fish in amounts slightly greater than what is recommended should not present a health hazard if only done occasionally, such as eating fish caught during an annual vacation.
- Nursing and pregnant women and young children may be more sensitive to the harmful effects of mercury and should be particularly careful about following the notification. Because contaminants accumulate over time, women who plan on becoming pregnant within a year, or are already pregnant, should exercise more caution than the recommendations below. The same is true for children under six years of age. In this way, the levels of chemicals stored in the body can be reduced over time.
- The limits given below for each species assume that no other contaminated fish is being eaten. If you consume several different listed species from the same area, or the same species from several areas, your total consumption still should not exceed the amount recommended for the fish with the fewest recommended meals. One should also realize that fish from other areas of the State may also be contaminated with mercury, and that the results of consuming all fish are cumulative. One simple approach is to just use the lowest recommended amount as a guideline to consumption. A meal for a person weighing approximately 150 pounds is assumed to be an eight-ounce serving; meal size should be adjusted according to body weight.

1 meal/month	1 meal/week
Spotted bass	Bluegill
Largemouth bass	Green sunfish
Smallmouth bass	Brown trout
	Rainbow trout
	Black crappie
	Channel catfish

Appendix 3. Public Workshop Questions and Comments with Responses

Are there differences in mercury concentration between natural and planted fish?

Planted trout can generally be distinguished from resident fish by the worn appearance of the tail and other fins on the belly side. Mercury in recently planted trout may, in fact, have lower mercury concentrations than native fish with a longer residence time in a contaminated water body. This is primarily because native trout have been eating other aquatic organisms from the contaminated water body for a longer period of time. However, this theory has not been evaluated in the Sierra Lakes reservoirs. Because planted fish may have been fed fishmeal that contains mercury or other contaminants, guidelines for trout consumption should be followed regardless of presumed fish origin.

What is the definition of a site in the report and advisories? Aren't there some "hot spots" in river or creek sites in the Sierra Lakes region?

In the report, "sites" were considered to be areas in reservoirs or creeks and streams where USGS collected fish samples. Typically multiple sites were used as collection points in each water body. In order to achieve a representative sample size for a species, it was necessary to combine all sites in a water body for evaluations in the report and for advisories. This means that each of the reservoirs and the three major river or creek systems (the Bear River, the South Yuba River, and Deer Creek) were considered as independent water bodies with multiple collection sites. One exception to this was that river and creek sites above the mining area were considered separately from those below.

There appeared to be higher mercury concentrations at Little Deer Creek at Pioneer Park and the Bear River at Dog Bar Road compared to nearby collection sites; however, sample size was not sufficient to determine this with confidence. For Little Deer Creek at Pioneer Park, consumption advice will be the same even if the same mercury levels in fish at that site are later confirmed. For Bear River at Dog Bar Road, consumption advice could be somewhat more restrictive if the same mercury concentrations were confirmed through additional sampling

How were sampling sites in rivers and creeks selected? Does the literature show a predictable relationship between mercury levels in fish at sites at increasing distances downstream from pollution sources?

USGS sampled at sites where they and anglers had river or creek access and where they could catch fish. Because mercury availability to fish is dependent on many environmental, chemical and hydrological factors in a water body, mercury levels in fish cannot be predicted with confidence based on proximity to mercury pollution sources.

Is there a way to translate the advice so it is not so complicated? Can baseline advice for the region be included?

OEHHA makes every attempt to strike a balance between accuracy and simplicity in their fish consumption guidelines. In order to further simplify the advice, it would have to be made more conservative (e.g., applying advice for the most contaminated fish at a lake to all fish at that lake or from the worst lake to all other lakes). This approach would needlessly limit fish consumption for some species or some water bodies. It might also unduly frighten people into thinking that all fish consumption was unhealthy.

Baseline advice is included in the advisory for all fishers in the form of the U.S. EPA national freshwater sport fish consumption advice for woman who are pregnant or may become pregnant, nursing mothers, and young children and the OEHHA general advice for sport fish consumption for females beyond their childbearing years and adult males. An adequate and unbiased database of concentrations of mercury in fish for water bodies throughout California or in a defined subregion would be required in order to derive baseline statewide or regional advice for a species or group (e.g., black bass or trout). We are investigating the information and resources needed to design and implement a random sampling design that could be used to develop data for this sort of baseline advice. This will be more complicated with multiple contaminants.

Are there different forms of mercury in the environment?

Mercury is found in several forms in the environment; however, in fish, by far the most predominant form is methylmercury. Because methylmercury is more toxic than other environment forms, in an effort to be health protective, all fish mercury is assumed to be methylmercury and risk assessments are conducted accordingly.

Are mercury levels in fish higher at Camp Far West Reservoir because it is warmer than the other reservoirs? How critical is temperature in determining mercury availability to fish?

Camp Far West Reservoir is comparatively shallower and warmer than the other reservoirs. Although temperature does affect mercury availability, there is no strict correlation available to predict mercury concentration in fish based on water temperature. Temperature may be a factor contributing to higher mercury concentrations in fish at this reservoir but it is not likely to be the only factor. A US Geological Survey study of mercury bioaccumulation through the food web at this reservoir may shed some light on the higher concentrations at Camp Far West Reservoir.

Uniform posting of fish consumption advisories at fishing areas throughout the state would be good to increase public communication and awareness. This is done for mussel quarantines. Is there a process for posting advisories, for example, on kiosks near the launch ramp? If there are no posting requirements, who is required to tell people of the advisories? Wouldn't it be useful to keep this information in the news on a regular basis?

There is no specific legislative mandate to post sport fish consumption advisories, nor is there an existing mechanism to fund the creation and posting of signs listing sport fish consumption advisories. OEHHA notifies county health agencies of advisories and provides information that can be posted. Advisories are listed in the Department of Fish and Game's fishing regulations handbooks as well as on the OEHHA website. Copies of specific advisories have been posted at park kiosks in some places. OEHHA has worked on task forces with county and other local agencies on projects to inform the public of fish consumption advisories issued for the San Francisco and Santa Monica bays. A universal sign providing fish consumption advice in several languages has been developed for San Francisco Bay. OEHHA is working with a new task force in the Sacramento-San Joaquin-Delta watershed to educate and inform people about fish contamination issues and sport fish consumption advisories there.

What are human blood levels of mercury? What are desirable tolerance levels and who sets them? Are there guidelines for physicians? How good is human blood as an assay of mercury exposure?

There are no tolerance levels set for blood mercury levels in the U.S. There is no specific agency responsible for setting such levels. Clinical laboratory reports may include a reference range for comparison. Reference ranges are established by testing a large number of "normal" people and reporting the range of values measured. A measurement outside of the reference range does not necessarily indicate illness; it can occur by chance and is a signal that further investigation is warranted. In a recent national survey of about 1700 women, the total mercury levels in whole blood ranged from <1-15 μg/L. For non-fish consumers, the background level in blood has been found to average 2 μg/L. The level in blood increases with increasing fish consumption and frequent fish consumers in the U.S. may have blood mercury levels greater than 15 μg/L. In high fish eating populations in different parts of the world, some individuals may have blood mercury concentrations as high as 200 μg/L. The first methylmercury reference dose (RfD) was set based on central nervous system symptoms seen in adults during a mass-poisoning epidemic in Japan. The lowest blood mercury concentration associated with such symptoms in those individuals was 200 μg/L. In setting the most recent RfD for methylmercury based on data modeled from cord blood mercury levels, U.S. EPA determined that maternal blood mercury levels of 46-79 μg/L were the minimum concentrations associated with subtle neurodevelopmental effects in fetuses. Other than these levels, there are no established guidelines for physicians that associate mercury levels in blood to specific health complaints or clinical effects. Blood mercury concentration is a better biomarker of mercury exposure than are urine or hair mercury levels.

Does mercury leave the body? How long does it take?

Methylmercury is slowly eliminated from the body, primarily through the feces (and breast milk for lactating women). Approximately 1% of the total methylmercury present in the body is excreted each day. The whole-body half-life of methylmercury in humans has been estimated to range from about 44 to 74 days. That means that approximately one-half of an ingested dose will be eliminated in 44-74 days. One-half of the remaining dose will be eliminated in the next 44-74 days, and so on, until the majority of the methylmercury has been eliminated in about one year, assuming that no further methylmercury exposure has occurred. However, in studies of some highly poisoned individuals, mercury levels in brain tissue were still greatly elevated some two decades after their exposure.

Isn't methylmercury fat-soluble? How is mercury mobilized in the body?

Methylmercury is slightly fat-soluble, allowing it to move easily through human tissues. After being absorbed in the gastrointestinal tract, methylmercury enters the blood where it is found primarily in the red blood cells. The blood distributes methylmercury and inorganic mercury throughout the body. Once in the body, methylmercury is slowly converted to divalent inorganic mercury prior to excretion, primarily in bile and feces. Methylmercury can also be eliminated directly via this route. Divalent mercury binds to protein in the blood and other tissues. But some divalent mercury remains unbound and there is an equilibrium between bound and unbound mercury. As a result, mercury can be mobilized from tissue, redistributed, and eliminated. Mercury in the brain, however, is harder to eliminate due to the blood-brain barrier. The highest concentration of inorganic mercury is found in the liver and kidney, where it complexes with the metal-binding protein metallothionein.

Are there documented cases of health problems associated with mercury toxicity from fish consumption? Should you promote catch and release fishing?

Over the years, there have been isolated cases of mercury toxicity reported as a result of heavy consumption of high-mercury *commercial* fish (e.g., swordfish and Chilean sea bass) in this country. Recently, a doctor from the San Francisco area reported that a number of her patients who consumed large amount of commercial fish had relatively high blood mercury concentrations. Although these patients complained of non-specific symptoms (e.g., headache, fatigue) that resolved when fish consumption was restricted, it cannot be conclusively determined that these symptoms were the result of mercury exposure. Subtle effects of excessive mercury exposure in children are difficult to detect and would likely go unrecognized.

OEHHA's role is to establish and promote safe consumption guidelines for sport fish. OEHHA favors catch and release fishing and recognizes that it can serve multiple purposes: it helps preserve fish populations as a resource; it promotes recreational opportunities for other anglers; and it is a means to stay within safe consumption limits while continuing to enjoy fishing.

If a subsistence fisher regularly consumes high-mercury fish, how long would it be before symptoms might develop?

If a person were exposed to sufficient methylmercury from fish to exhibit symptoms of toxicity, the time that it would take to develop such symptoms would depend on the amount of fish that they consume, the mercury concentration in the fish that they eat, and the frequency of their consumption. In one case of suspected methylmercury toxicity that was reported in New York in the 1970s, a woman developed symptoms of headache, lethargy, blurred vision, and tremor over a period of ten months while she was consuming approximately 12.5 ounces per day of swordfish estimated to average 1.0 to 1.5 ppm mercury.

Is mercury in fish a national problem? What about other chemicals in fish?

Although California is relatively unique in that we have local sources of mercury from mercury mines in the coast range and gold mining operations in the Sierra Nevada foothills, many water bodies in other parts of the United States as well as other countries have mercury contamination problems because of aerial deposition of mercury from coal burning and other industrial sources. The majority of fish consumption advisories in the United States have been issued because of mercury contamination. Other contaminants may also be found in fish from some regions, particularly persistent organic pollutants such as PCBs and DDTs. OEHHA recommends continued comprehensive monitoring of sport fish throughout the state for mercury, other trace metals, and organic pollutants. It is not possible to determine the extent of contamination problems without monitoring.

Isn't it important to note that these are just the lakes that have been studied and that other lakes may also have contamination problems?

Yes, other lakes that have not been studied may also have contamination problems, and OEHHA supports comprehensive monitoring of more water bodies. OEHHA recognizes that sport fish in most water bodies have not been evaluated for their safety for human consumption. For this reason, we recommend that, when site-specific advice in not available, females of childbearing age and children age 17 and younger follow the U.S. EPA national freshwater sport fish consumption advice for woman who are pregnant or may become pregnant, nursing mothers, and young children, and that females beyond their childbearing years and adult males follow the OEHHA general advice for sport fish consumption.

Are there preliminary contamination data available from other lakes, such as Folsom and Clementine, downstream from historic mining sites?

Sport fish are being collected at other sites (e.g., Lake Natoma) for analysis, but more sampling is needed.

Have there been studies on arsenic concentrations in local fish?

USGS has not analyzed fish from water bodies in the area covered by this report and advisory. There were a limited number of samples from this area for which arsenic was measured 10-20 years ago in the Toxic Substances Monitoring Program. The arsenic levels in these samples were not elevated. The highest concentrations were in clams and crayfish. Because arsenic in fish is found largely in the form of the relatively non-toxic arsenobetaine, this is not considered a high priority for study. Inorganic arsenic data is needed to do a health evaluation.

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